Nova Scotia Examinations

Physics 12

Teacher Information Guide

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Introduction

The purpose of this *Teacher Information Guide* is to provide teachers with information about the Nova Scotia Examinations (NSE) in Physics 12. Teachers are encouraged to share the contents of the guide, particularly the sample questions and answers, with their students.

> The document *Atlantic Canada Science Curriculum, Physics 12* is intended to provide teachers with an overview of the outcomes framework for the Physics 12 course. Teachers should consult that document, which includes some suggestions to assist teachers in designing learning experiences and assessment tasks.

Nova Scotia Examinations in Physics 12 are designed to reflect the tables of specifications (page 3), which are derived from the Atlantic Canada Science Curriculum for grade 12 physics. The outcomes listed in the appendix (pages 15–19) of this *Teacher Information Guide* are those that are used to construct the examinations. Not all outcomes listed in the appendix will be included on any one examination.

Some examination questions will assess achievement of an individual outcome, while other questions will incorporate a number of outcomes. At present the examinations are solely written assessments composed of a variety of question types that are developed to represent different cognitive levels and are keyed to specific topics.

NOTE: current electricity is an optional topic in Physics 12, therefore, the physics examination will not include questions related to this topic and its outcomes.

NSE in Physics 12 will be administered on **January 30** and **June 20, 2003.**

Explanation of Cognitive Levels

The NSE in Physics 12 contain questions at three cognitive levels. Cognitive levels indicate the type of intellectual process required to respond to each question. Cognitive levels are NOT degrees of difficulty. A knowledge question (level 1) is extremely difficult if the student cannot remember the answer. A question at level 2 that requires the student to equate expressions for F_c and F_g can be quite easy for the student who recognizes the pattern.

Knowledge (Level 1)

Knowledge refers to test situations that emphasize the remembrance, either by recognition or recall, of ideas, material, or phenomena. This level comprises knowledge of terminology, specific facts (definitions, laws, principles, etc.), conventions, classifications and categories, methods of inquiry, principles and generalizations, and theories and structures. Stem words include: *what, list, define, name, describe.*

Comprehension and Application (Level 2)

Comprehension refers to responses that demonstrate an understanding of the literal message contained in a communication, meaning that the student is able to translate, interpret, or extrapolate. Translation refers to the ability to put a communication into another language. Interpretation involves re-ordering ideas (inferences, generalizations, or summaries). Extrapolation is the ability to estimate or predict based on an understanding of trends and tendencies. Stem words include: *explain, interpret, summarize, give examples, predict, translate.*

Application requires the student to select and apply an appropriate abstraction (theory, principle, idea, method) to a new situation. Stem words include: *compute, solve, apply, construct*.

Analysis+ (includes Synthesis and Evaluation) (Level 3)

Analysis comprises the ability to recognize unstated assumptions, to distinguish a conclusion from statements that support it, to recognize facts or assumptions that are essential to a main thesis, to distinguish cause-effect relationships from other sequential relationships, and to recognize a writer's viewpoint. Stem words include: *why does...work?, distinguish, how are the parts of...related?*

Synthesis is the production of something original from the component parts identified in analysis. Stems include: *propose ways to test a hypothesis, design an experiment to investigate..., formulate and modify a hypothesis related to..., make generalizations based on the analysis of data.*

Evaluation is defined as making judgements about the value of ideas, solutions, and methods. It involves the use of criteria to appraise the extent to which details are accurate, effective, economical, or satisfying. Evaluation includes developing and applying given criteria to judgements of work done, indicating logical fallacies in arguments, and comparing major theories and generalizations. Stems include: *What prediction can you make based on your data?, How could you refine the experiment to improve the data?, What are the positive and negative implications of...?, What course of action do you recommend based on the data/information?*

Note: Examination questions that require primarily algebraic problem solving are categorized by level according to the following guidelines:

- If the solution requires the student to make direct replacement of data in a single expression, the question will be considered level 1.
- If the solution requires several equations or substantial rearrangement, the question will be considered level 2.
- A level 3 question will require the interpretation of supplied data and/or a degree of analysis beyond the typical application of formulae.

Sample questions and answers with level designations are provided later in this document.

Tables of Specifications

Question Format	Number of Questions	Percent Emphasis	Cognitive Level
Selected Response (multiple choice)	40	40%	Levels 1 and 2
Constructed Response (written response and algebraic problem solving)	variable	60%	Levels 2 and 3

Topic	Cognitive Levels			
	level 1	level 2	level 3	%
Force, motion, work, and energy	17	28	10	55
Fields	6	10	5	21
Waves and nuclear physics	5	7	0	12
Radioactivity	7	5	0	12
Percent by question level	35	50	15	100

Note: The examination will include a case study worth 10% and will be based on a topic from one of the four content areas. Students will be required to read material provided and respond to a group of questions.

Questions with science, technology, society, and environment (STSE) implications will appear throughout the examination.

Sample Questions and Answers

Selected Response Questions

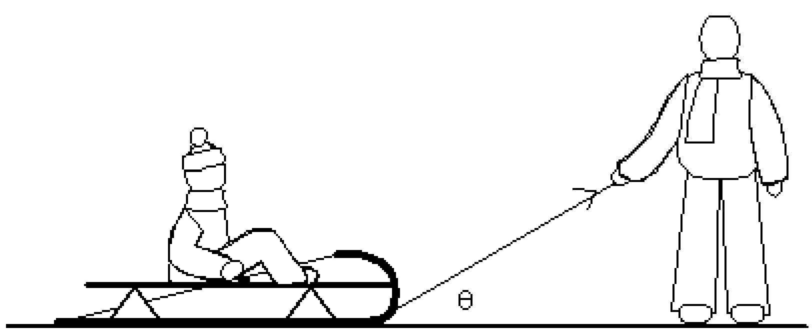
Multiple Choice: These questions offer the student four choices, three of which are plausible distractors, and one that is the correct response. Questions may be either level 1 or level 2.

1. What is the centripetal force acting on a 15 kg mass that is moving at a speed of 2.0 m/s in a circle of radius 3/0 m? ***[level 1, outcome 325–12]***

   A 0.3.3 N
   B 6.7 N
   C 10. N
   ✓D 20. N

   ANSWER: $F_c = \dfrac{mv^2}{r} = \dfrac{15kg \times 4.0\ \mathrm{m}^2/\mathrm{s}^2}{3.0\ \mathrm{m}} = 20.\ \mathrm{N}$

2. In the diagram below, a force $\vec{F}$ is applied to a rope connected to a toboggan. The rope makes an angle θ to the ground. The magnitude of the horizontal component of the force depends on which of the following? ***[level 2, outcome ACP 1]***



   A. the magnitude of the angle only
   B. the magnitude of the force only
   ✓ C. the magnitude of both the angle and the force
   D. neither the angle nor the force

Constructed Response Questions

These questions may require the solution of a problem or a written response, at any of the three cognitive levels.

1. A 25 kg mass is observed moving in a circular path of 1.0×10^2 m radius at a speed of 10. m/s. What centripetal force is required to maintain this motion? **[level 1, outcome 325–12]**

ANSWER: $F_c = mv^2/R = 25 \text{ kg } (10. \text{ m/s})^2/1.0 \times 10^2 \text{ m} = 25 \text{ N}$

2. A person weighs 800 N on the surface of the Earth. What would that person's weight be 10 times as far from the Earth's centre? **[level 2, outcome 215–2]**

ANSWER: The gravitational force varies inversely as the square of the ratio of the distances from the centre. At ten times as far away the person would weigh 100 times less, or 800 N/100 = 8 N.

Alternately, $F_1/F_2 = (r_2)^2/(r_1)^2 = 800 \text{ N}/F_2 = (10)^2/(1)^2$, and F_2 (at 10 times) = 8 N

3. A projectile is launched horizontally from a raised position. Explain why it is not possible to use simple linear kinematics and dynamics equations to determine the velocity at some instant in the flight. **[level 2, outcome 325–6]**

ANSWER: The equations available are for use in one dimensional problems. Projectile motion involves component analysis in two planes. Although each plane, horizontal and vertical, can be solved independently using linear equations, the final value for the instantaneous velocity will require a vector solution.

4. The handle of a lawn mower makes an angle of 40.0^0 with the horizontal. A push of 180. N must be applied to the handle to keep the mower at a constant speed along the level lawn. Given that the coefficient of friction between the lawn mower and the lawn is 0.300, calculate the mass of the lawn mower. **[level 3, outcome ACP 1]**

ANSWER: $\mu = F/N$ and $N = F/\mu = (\text{Cos } 40^0)(180. \text{ N}) = (.766 \times 180. \text{ N})/0.300 = 460 \text{ N}$

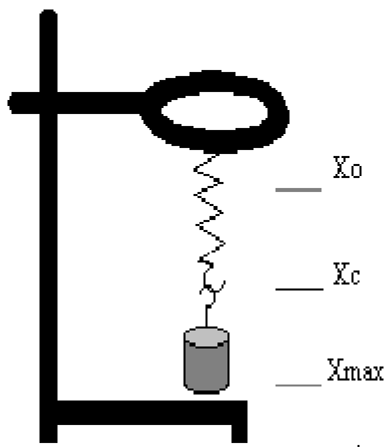
But N = weight of mower plus vertical force due to the 180. N at 40^0.

So, weight of mower = N - vertical force due to 180. N at 40^0.

Weight of mower = 460. N - (Sin 40^0 x 180. N) = 460 N - 116 N = 344. N

The mass of the mower = 344. N/ 9.80 m/s^2 = 35.1 kg

5. Using a sketch and one or two paragraphs, explain the relationship among displacement, speed and acceleration when a mass is attached to a vertically mounted spring and allowed to oscillate up and down. **[level 2, outcome 327–2]**



ANSWER: If the mass is dropped from the x_o position where the spring is completely unstretched, it will experience a downward acceleration, which is the result of the sum of the spring force and the gravitational force. The mass will continue to gain speed at a decreasing rate from x_o to x_c, reaching maximum speed at x_c. From x_c to x_{max}, the force in the spring will continue to increase, resulting in a net upward acceleration, causing the speed to decrease at an increasing rate until $v = 0$ at x_{max}. The mass will then begin to move upward at increasing speed to x_c, and decreasing speed to x_o.

Case Study: *This question requires students to construct a response that involves the analysis of supplied material.*

DISPOSAL OF NUCLEAR WASTE

Three articles are provided for you to read, followed by a series of questions related to the articles and material you have studied in class. Answer the questions that follow the articles in the spaces provided.

Article 1:

Atomic Energy of Canada Limited (Aecl) Proposal for Handling Nuclear Waste

AECL developed the following concept for disposing of nuclear fuel waste:

- Dispose of nuclear fuel waste at about 500 to 1 000 metres underground in stable rock formations.
- Place the waste in a disposal vault, a network of horizontal tunnels and disposal rooms, with vertical shafts extending from the surface to the tunnels.
- Place waste containers in the disposal room.
- Fill and seal disposal rooms with buffer, backfill, and other vault seals.
- Combinations of engineered and natural barriers protect human health and the natural environment in the long term.
- Security and monitoring could be continued if desired, and retrieval would be possible.

Article 2:

An Independent Commission to Re-evaluate Radioactive Waste Policy

In 1995, a senate bill was introduced in the United States that would establish an independent Presidential Commission to completely review and re-evaluate our nation's radioactive waste policy.

Few dispute that our nation's existing radioactive waste policies have failed. While federal government production of new atomic waste has slowed (clean-up of weapons plants may actually create waste), commercial nuclear reactors and associated facilities continue to generate hazardous material, with no permanent solution for its storage in sight.

The Nuclear Industry's "Solution"

The nuclear power industry regards atomic waste as a commodity--something that should be reprocessed or recycled whenever possible. Because this is neither economically nor socially feasible, and faced with the problems noted above, the industry has endorsed the concept of "interim" offsite storage, which essentially means "move it anywhere but get it off our property." Most "interim" storage schemes would place the high-level waste either in Nevada (apparently because of the dubious Yucca Mountain connection, since Nevada has no nuclear power plants) or on Native American lands. But "interim" storage has run into substantial criticism since it fails to cope with the central issue: what our nation should do with the waste on a more permanent basis, or whether we should generate radioactive materials in the absence of a permanent solution for their storage. In the meantime, radioactive waste for the most part is being stored on-site at nuclear reactors.

Although the nuclear power industry has tried to portray new "low-level" radioactive waste dumps as essential to ensure continued use of nuclear medicine, the vast majority of medical radioactive waste is both small in amount of radioactivity and is short-lived, making effective storage quite reasonable. Nuclear reactor waste, on the other hand, is both long-lived and can be lethally dangerous. In addition, unlike medical waste, nuclear reactor waste includes such hazardous elements as Plutonium-239, which has a hazardous life of 240,000 years, far beyond the 100-year control period proposed for "low-level" radioactive waste dumps. This raises substantial issues as to whether the current classification scheme for radioactive waste holds scientific credibility, or whether it is merely a convenience to the nuclear industry. "Interim" storage of high-level waste, and establishment of potentially national or regional "low-level" nuclear waste treatment centres and dumps also raises the spectre of widespread transportation of deadly atomic garbage. "Interim" storage is not a solution for a sound radioactive waste management policy. It is simply a stop-gap measure aimed at removing the waste from where it now rests--with the nuclear utilities--in order to give utilities room to make still more nuclear waste--with no permanent solution in sight, and to transfer the liability for accidents from the utilities to taxpayers.

Article 3:

Accelerator Transmutation of Radioactive Waste

Restructuring the Atom

During 1996, I became aware of a developing technology, known as "Accelerator Transmutation of Waste" (ATW), which offers the promise of altering or "transmuting" plutonium and radioactive, spent nuclear fuel, into short-lived radioisotopes and inert, harmless substances.

The premise of ATW is that protons, propelled by very high-energy accelerators, would target the waste, producing neutrons which, through nuclear fission, would convert most radioactive substances into ordinary, non-radioactive ones. There have already been two international scientific conferences on the subject; (Las Vegas, Nevada, 1995 and Kalmar, Sweden, 1996.) The prognosis is encouraging.

This transmutation process, which requires no initial reprocessing of the waste, would occur at a "subcritical" level (which precludes Chernobyl-type runaway chain reaction). Further, the heat generated by the fission would provide the energy to operate the accelerator system. (It could also produce significant amounts of energy for commercial use!)

A Promising Alternative

Some scientists at the U.S. Los Alamos National Laboratory have already concluded that a full scale effort to exploit the capabilities of ATW could preclude the need for long-term permanent geological storage of spent reactor fuel. They also suggest that the process could destroy all the surplus weapons plutonium generated by the U.S. and the former Soviet Union. (Thus, there would be no need for Canada to assume the risks and problems associated with proposals to import and use the plutonium to fuel CANDU reactors.)

As for the pros and cons of ATW, there are many questions that remain to be answered, but it is obvious that sufficient in-depth research and development has already taken place in other countries to underscore its importance as an emerging, rational, and promising alternative to long-term geological storage.

> The increasing probability that we may be able to render most nuclear wastes inert, in our own lifetimes and in our own generations, is sufficient reason not to impose the risks of nuclear waste burial on countless future generations. For the time being, above ground, on-site, monitored retrievable storage, is the most prudent and logical alternative for management of high-level radioactive waste while alternatives to long-term, permanent underground burial are being studied.

Please answer the following questions, related to the previous readings, in the spaces provided.

1. Isotopes of which two elements are produced when a $^{238}_{92}U$ atom is bombarded by a neutron? (1 point) ***[level 1, outcome 329–4]***

✓A. Barium and Krypton
B. Plutonium and Krypton
C. Radium and Boron
D. Radium and Plutonium

2. What is the product of uranium fission reactors that poses the most serious problem for long term storage? (1 point) ***[level 1, outcome 329–4]***

A. $^{144}_{56}Ba$
B. $^{3}_{1}H$
✓C. $^{239}_{94}Pu$
D. $^{235}_{92}U$

3. Using the concept of half-life, explain why radioactive waste poses a special disposal concern. (2 points) ***[level 2, outcome 329–4, 118–2]***

ANSWER: The half-life of a radioactive material is the length of time it takes for half the atoms in a sample of a radioisotope to decay spontaneously. Pu 239 has a half-life of 2.44×10^4 years. Even after 24,000 years, half the material is still hazardous.

4. Explain two concerns people have about the long term storage of radioactive waste, other than the half-life of the stored material. (2 points) ***[level 2, outcome 118–2]***

ANSWER: Public safety requires safe, secure storage for many thousands of years, which cannot be guaranteed either politically or geologically. If the rate of production exceeds the rate of decay, the problem becomes more serious. Storage proposals appear to be very costly. Transportation form source to storage site presents a serious short-term hazard.

5. What are two reasons why radioactive medical waste is not a major concern? (2 points) ***[level 1, outcome 118–2]***

ANSWER: Medical radioactive waste is not a major concern because the quantity is small and the half-life is relatively short.

6. Accelerator Transmutation of Radioactive Waste (ATW) is promoted in one of the articles as a solution/alternative to the disposal of radioactive waste. Evaluate the process as presented in the article on the basis of criteria you clearly identify. (2 points) ***[level 3, outcome 118–2]***

ANSWER: ATW should address the problems of long half-life and transportation if it is to be considered a credible alternative to storage. Transmutation solves the long-term storage problem by eliminating it, since the hazardous isotopes are changed to stable, harmless ones. The problem of transportation can only be solved if an ATW facility is built on-site at every reactor, which could be costly.

Examination Construction

Nova Scotia Examinations in Physics 12 are constructed in accordance with the tables of specifications (p. 3), using questions (items) that have met the following criteria:

- content review by the provincial physics examination committee for match with outcomes as listed in the appendix, bias, construction flaws.
- field-testing under monitored conditions in classes following the Atlantic Canada Science Curriculum for grade 12 physics
- statistical analysis following field-testing to determine levels of difficulty and discrimination

Item Banking

Teachers are encouraged to submit test items of all types for consideration by the Nova Scotia Examination Committee for Physics.

Send materials to:

Nova Scotia Examination Committee for Physics
Testing and Evaluation Division
Nova Scotia Department of Education
P. O. Box 578
Halifax, N. S. B3J 2S9

(fax 902 424 0614)

Conventions in Physics

The examination committee will use the following conventions in presentation and scoring:

- Direction will be presented in compass bearing format (045°) and also as degrees north of east (45° N of E). Other forms will be acceptable in student answers provided they are clearly expressed.
- Proper use of significant figures is expected in student responses. Rounding will be done after <u>each operation</u> using the split five rule. However, in constructed responses, students will be given some latitude. In general, only gross errors in value and answers presented with more than one inappropriate additional digit will be penalized.

Appendices

Specific Curriculum Outcomes for Nova Scotia Examinations in Physics 12

Specific curriculum outcome statements describe what students are expected to know and be able to do at each grade level. They are intended to help teachers design learning experiences and assessment tasks.

Note: Questions on the examination are based on the statements below and are arranged according to the tables of specifications (p. 3). Teachers have been provided with the *Atlantic Canada Science Curriculum, Physics 12* for their complete course of study. The information found in the brackets contains the specific curriculum outcome reference to the *Atlantic Canada Science Curriculum, Physics 12*.

Force, Motion, Work, and Energy

Dynamics Extension

1. use vector analysis in two dimensions for systems involving two or more masses, relative motions, static equilibrium, and static torques (ACP–1)

Collisions in Two Dimensions

2. apply quantitatively the laws of conservation of momentum to one- and two-dimensional collisions and explosions (326–3)

3. determine in which real-life situations involving elastic and inelastic interactions the laws of conservation of momentum and energy are best used (326–4)

Projectiles

4. construct, test and evaluate a device or system on the basis of developed criteria (214–14, 214–16)

5. analyse qualitatively and quantitatively the horizontal and vertical motion of a projectile (325–6)

Circular Motion

6. describe uniform circular motion using algebraic and vector analysis (325–12)

7. explain quantitatively circular motion using Newton's laws (325–13)

Simple Harmonic Motion

8. identify questions, analyse, compile, and display evidence and information to investigate the development over time of a practical problem, issue, or technology (212–3, 214–3, 115–5)

9. explain quantitatively the relationship between potential and kinetic energies of a mass in simple harmonic motion (327–4)

10. explain quantitatively the relationship between potential and kinetic energies of a mass in simple harmonic motion (327–4)

11. compile and organize data, using data tables and graphs, to facilitate interpretation of the data (213–5)

Universal Gravitation

12. explain qualitatively Kepler's first and second laws and apply quantitatively Kepler's third law (ACP–2)

13. use appropriate numeric and graphic analysis to interpret and apply the law of universal gravitation to orbital rotations (215–2)

14. distinguish between scientific questions and technological problems (115–1)

15. analyse and describe examples where technologies were developed based on scientific understanding (116–4)

16. analyse society's influence on scientific and technological endeavours (117–2)

Fields

Magnetic, Electric, and Gravitational Fields

17. explain the roles of evidence, theories and paradigms, and peer review in the development of the scientific knowledge associated with a major scientific milestone (114–2, 114–5, 115–3)

18. communicate questions, ideas and intentions, and receive, interpret, understand, support and respond to the ideas of others (215–1)

19. describe magnetic, electric, and gravitational fields as regions of space that affect mass and charge (328–1)

20. describe magnetic, electric, and gravitational fields by illustrating the source and direction of the lines of force (328–2)

21. describe electric fields in terms of like and unlike charges, and magnetic fields in terms of poles (328–3)
    –draw the magnetic field around one or more bar magnets in various orientations
    –describe the Earth's magnetic field and how it changes with time

Coulomb's Law

22. define and delimit problems, estimate quantities, and interpret patterns and trends in data, and infer or calculate the relationship among variables (212–2, 213–4, 214–5)

23. compare Newton's Law of universal gravitation with Coulomb's Law, and apply both laws quantitatively (328–4)

Electric Circuits **(Optional—not included on the examination)**

Electromagnetic Induction

24. analyse, qualitatively and quantitatively, electromagnetic induction by both a changing magnetic flux and a moving conductor (328–7)
    –use Lenz's law to predict the directions of induced current
    –describe the construction and operation of isolation, step-up, and step-down transformers

25. analyse, qualitatively and quantitatively, the forces acting on a moving charge in a uniform magnetic field (328–5)

26. describe the magnetic field produced by a current in a long straight conductor, and in a solenoid (328–6)
    –illustrate the use of the "hand rules," which are useful to describe the field about a current-carrying conductor
    –describe the "hand rule" for motors

Generators and Motors

27. describe and compare direct current and alternating current (ACP–4)

28. compare and contrast the ways a motor and generator function, using the principles of electromagnetism (328–9)

Waves and Modern Physics

Quantum Physics

29. explain how quantum physics evolved as new evidence came to light and as laws and theories were tested and subsequently restricted, revised, or replaced, and use library and electronic research tools to collect information on this topic (115–7, 213–6)

30. describe how the quantum energy concept explains both black-body radiation and the photoelectric effect (327–9)

31. explain qualitatively and apply the formula for the photoelectric effect (327–10)

Compton and de Broglie

32. explain how photon momentum revolutionized thinking in the scientific community (115–3)

33. apply and assess alternative theoretical models for interpreting knowledge in a given field (214–6)

34. explain quantitatively the Compton effect and the de Broglie hypothesis, using the laws of mechanics, the conservation of momentum, and the nature of light (329–1)

Particles and Waves

35. summarize the evidence for the wave and particle models of light (327–11)

Bohr Atoms and Quantum Atoms

36. explain quantitatively the Bohr atomic model as a synthesis of classical and quantum concepts (329–2)

37. explain the relationship among the energy levels in Bohr's model, the energy difference between levels, and the energy of the emitted photons (329–3)

Radioactivity

Natural and Artificial Sources of Radiation

38. describe sources of radioactivity in the natural and constructed environments (329–5)

39. identify, analyse, and describe examples where technologies were developed based on scientific understanding, their design and function as part of a community's life, and science- and technology-related careers (116–4, 116–6, 117–5, 117–7)

40. use the quantum-mechanical model to explain naturally luminous phenomena (329–7)

41. apply quantitatively the law of conservation of mass and energy using Einstein's mass-energy equivalence (326–9)

42. select and integrate information from various print and electronic sources or from several parts of the same source (213–7)

43. develop appropriate sampling procedures (212–9)

44. select and use apparatus and materials safely (213–8)

45. demonstrate a knowledge of WHMIS standards by selecting and applying proper techniques for handling and disposing of lab materials (213–9)

Radioactive Decay

46. describe the products of radioactive decay, and the characteristics of alpha, beta, and gamma radiation (329–4)

Fission and Fusion

47. compare and contrast fission and fusion (329–6)

48. analyse examples of Canadian contribution to a particular development of science and technology (115–5, 117–11)

49. identify, develop, present, and defend a position or course of action based on identifying multiple perspectives that influence the issue, and on interpreting data and the relationship among variables (214–15, 215–4, 215–5)

50. analyse and evaluate, from a variety of perspectives, using a variety of criteria, the risks and benefits to society and the environment of a particular application of scientific knowledge and technology (118–2, 118–4)

Nova Scotia Examinations Physics 12
Formula Sheet

KINEMATICS

$$\vec{v}_{ave} = \frac{\Delta\vec{d}}{t} \qquad \Delta\vec{d} = \left(\frac{\vec{v}_f + \vec{v}_i}{2}\right)t$$

$$a = \frac{\vec{v}_f - \vec{v}_i}{t} \qquad \Delta\vec{d} = \vec{v}_i t + \frac{1}{2}\vec{a}t^2$$

$$v_f^2 = v_i^2 + 2ad$$

$$v_c = \frac{2\pi r}{T} \qquad a_c = \frac{v_c^2}{r}$$

DYNAMICS

$$\vec{F} = m\vec{a} \qquad \vec{F}_g = m\vec{g} \qquad F_f = \mu F_N$$

$$\vec{F}_s = -k\vec{x} \qquad F_c = \frac{mv^2}{r} \qquad F_c = \frac{4\pi^2 mr}{T^2}$$

$$F_g = \frac{Gm_1m_2}{d^2} \qquad g = \frac{Gm_1}{d^2} \qquad k = \frac{r^3}{T^2}$$

$$T = 2\pi\sqrt{\frac{\ell}{g}} \qquad T = 2\pi\sqrt{\frac{m}{k}}$$

torque = length of torque arm × applied force

ELECTRICITY AND MAGNETISM

$$F_e = k\frac{q_1q_2}{r^2} \qquad V = IR$$

$$E = \frac{kq_1}{r^2} \qquad P = IV$$

$$F_m = B_\perp I\ell \qquad F_m = qvB_\perp$$

$$\vec{E} = \frac{\vec{F}_e}{q} \qquad I = \frac{q}{t}$$

$$V = \frac{\Delta E}{q} \qquad \frac{1}{R_{eq}} = \frac{1}{R_1} + \frac{1}{R_2} + \frac{1}{R_3}\text{etc}$$

$$V = \ell vB_\perp \qquad R_T = R_1 + R_2 + R_3\text{etc}$$

$$\frac{N_p}{N_s} = \frac{V_p}{V_s} = \frac{I_s}{I_p}$$

MOMENTUM AND ENERGY		QUANTUM AND NUCLEAR PHYSICS	
$\vec{p} = m\vec{v}$	$\vec{F}\Delta t = m\Delta\vec{v}$	$E_k = hf - hf_o$	$E = mc^2$
$W = Fd\cos\theta$	$E_k = \frac{1}{2}mv^2$	$E_n = \frac{-13.6}{n^2}eV$	$c = f\lambda$
$E_p = mgh$	$E_p = \frac{1}{2}kx^2$	$E_{photon} = E_f - E_i$	$p = \frac{h}{\lambda} = \frac{hf}{c}$
		$E_{photon} = hf = \frac{hc}{\lambda}$	$E_{photon} = pc$
		$\lambda = \frac{h}{mv}$	

Some Useful Information

acceleration due to gravity at the Earth's surface......**g** = 9.80 m/s^2
universal gravitation constant......**G** = 6.67 x 10^{-11} Nm^2/kg^2
Coulomb's law constant.......**k** = 9.0 x 10^9 Nm^2/C^2
magnitude of the charge on an electron.......1.60 x 10^{-19} C
Planck's constant.....**h** = 6.626 x 10^{-34} J/Hz or J•s
radius of Earth......6.37 x 10^6 m
radius of Earth orbit.....1.4957 x 10^{11} m
mass of Earth......5.98 x 10^{24} kg
speed of light in vacuum.....**c =** 3.00 x 10^8 m/s
mass of an electron.....9.11 x 10^{-31} kg
mass of a proton.....1.67 x 10^{-27} kg
atomic mass unit.....**u** = 1.6605 x 10^{-27} kg
rest mass of neutron.....1.008665 u
rest mass of proton.....1.007823 u
1 electron volt.....**eV** = 1.6 x 10^{-19} J

Periodic Table

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
1	1 **H** Hydrogen 1.01																	2 **He** Helium 4.00
2	3 **Li** Lithium 6.94	4 **Be** Beryllium 9.01											5 **B** Boron 10.81	6 **C** Carbon 12.01	7 **N** Nitrogen 14.01	8 **O** Oxygen 15.99	9 **F** Fluorine 18.99	10 **Ne** Neon 20.18
3	11 **Na** Sodium 22.99	12 **Mg** Magnesium 24.31											13 **Al** Aluminum 26.98	14 **Si** Silicon 28.09	15 **P** Phosphorus 30.97	16 **S** Sulphur 32.07	17 **Cl** Chlorine 35.45	18 **Ar** Argon 39.95
4	19 **K** Potassium 39.10	20 **Ca** Calcium 40.08	21 **Sc** Scandium 44.96	22 **Ti** Titanium 47.88	23 **V** Vanadium 50.94	24 **Cr** Chromium 51.99	25 **Mn** Manganese 54.94	26 **Fe** Iron 55.85	27 **Co** Cobalt 58.93	28 **Ni** Nickel 58.69	29 **Cu** Copper 63.55	30 **Zn** Zinc 65.39	31 **Ga** Gallium 69.72	32 **Ge** Germanium 72.61	33 **As** Arsenic 74.92	34 **Se** Selenium 78.96	35 **Br** Bromine 79.90	36 **Kr** Krypton 83.80
5	37 **Rb** Rubidium 85.47	38 **Sr** Strontium 87.62	39 **Y** Yttrium 88.91	40 **Zr** Zirconium 91.22	41 **Nb** Niobium 92.91	42 **Mo** Molybdenum 95.94	43 **Tc** Technetium (97.91)	44 **Ru** Ruthenium 101.07	45 **Rh** Rhodium 102.91	46 **Pd** Palladium 106.42	47 **Ag** Silver 107.87	48 **Cd** Cadmium 112.41	49 **In** Indium 114.82	50 **Sn** Tin 118.71	51 **Sb** Antimony 121.76	52 **Te** Tellurium 127.60	53 **I** Iodine 126.90	54 **Xe** Xenon 131.29
6	55 **Cs** Cesium 132.91	56 **Ba** Barium 137.33	57 * **La** Lanthanum 138.91	72 **Hf** Hafnium 178.49	73 **Ta** Tantalum 180.95	74 **W** Tungsten 183.85	75 **Re** Rhenium 186.21	76 **Os** Osmium 190.2	77 **Ir** Iridium 192.22	78 **Pt** Platinum 195.08	79 **Au** Gold 196.97	80 **Hg** Mercury 200.59	81 **Tl** Thallium 204.38	82 **Pb** Lead 207.2	83 **Bi** Bismuth 208.98	84 **Po** Polonium (208.98)	85 **At** Astatine (209.98)	86 **Rn** Radon (222.02)
7	87 **Fr** Francium (223.01)	88 **Ra** Radium (226.03)	89 ** **Ac** Actinium (227.03)	104 **Rf** Rutherfordium (261.11)	105 **Db** Dubnium (262.11)	106 **Sg** Seaborgium (263.12)	107 **Bh** Bohrium (262.12)	108 **Hs** Hassium (265)	109 **Mt** Meitnerium (266)	110 **Uun** Ununnilium (269)	111 **Uuu** Unununium (272)	112 **Uub** Ununbium (277)						
*			58 **Ce** Cerium 140.12	59 **Pr** Praseodymium 140.91	60 **Nd** Neodymium 144.24	61 **Pm** Promethium (144.91)	62 **Sm** Samarium 150.36	63 **Eu** Europium 151.97	64 **Gd** Gadolinium 157.25	65 **Tb** Terbium 158.93	66 **Dy** Dysprosium 162.50	67 **Ho** Holmium 164.93	68 **Er** Erbium 167.26	69 **Tm** Thulium 168.93	70 **Yb** Ytterbium 173.04	71 **Lu** Lutetium 174.97		
**			90 **Th** Thorium (232.04)	91 **Pa** Protactinium (231.04)	92 **U** Uranium 238.03	93 **Np** Neptunium (237.05)	94 **Pu** Plutonium (244.06)	95 **Am** Americium (243.06)	96 **Cm** Curium (247.07)	97 **Bk** Berkelium (247.07)	98 **Cf** Californium (251.08)	99 **Es** Einsteinium (252.08)	100 **Fm** Fermium (257.09)	101 **Md** Mendelevium (258.10)	102 **No** Nobelium (259.10)	103 **Lr** Lawrencium (262.11)		